ARTIFICIAL INTELLIGENCE

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Course information

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人工智能讲义,第10版

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Course homepage

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The chapter-by-chapter list is a syllabus that is subject to lectureper-week-per as scheduled

References

Stuart Russell and Peter Norvig Artificial Intelligence: A Modern Approach 4e (AIMA), Pearson, 2020 人工智能: 现代方法(第4版), 人民邮电出版社, 2022 The book website: aima.cs.berkeley.edu including codes github.com/aimacode and exercises aimacode.github.io/aima-exercises

Courtesy some sources (slides and figures) from the websites (without cited in each slide due to typeset space)

AI SLIDES: more and the newest materials than AIMA More references are included in the slides which would be required for reading as the course progresses, and it is encouraged to look for supplemental materials from other books, papers, and AI assistants to expand knowledge

- 1. Introduction
- 2. Search Algorithms I
- 3. Search Algorithms II
- 4. Constraint Satisfaction Problems
- 5. Logical Agents
- 6. Automated Reasoning
- 7. Automated Planning

Breadth: covering all major fields of AI (core requirement) Depth: going to the front of the fields (including all the slides with * for self-study, out of the course time)

- 8. Uncertain Knowledge and Reasoning
- 9. Making Decisions
- 10. Machine Learning
- 11. Natural Language Understanding
- 12. Robotics
- 13. Knowledge Representation*
- 14. Al Philosophy[†]
- [†]: maybe no teaching
- +: optional for undergraduate but requirement for graduate students
- #: requirement but may be self-taught due to limited time
- *: no requirement for the exam, learned as extended knowledge

— in detail each lecture

INTRODUCTION

1

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1 INTRODUCTION

1.1 Al

- Brief history
- The state of the art
- 1.2 Intelligent agent
 - Agent programs
 - Agent structures
 - Multi-agent systems⁺
- +: optional for undergraduate but requirement for graduate students

What is Al??

What is Intelligence?

Can a machine think? (behave like a thinking person) Thinking is some process that people engage in every day Intelligence is an <u>intuitive</u> concept

General intelligence is a general mental capability There is no precise definition of intelligence or thinking Artificial Intelligence (AI) attempts to understand intelligence entities, strives to building intelligent agents that perceive and act in an environment, and makes computers smarter in human-level intelligence

- understanding the principle of human intelligence
- making intelligent machines to replace human works

Does machine intelligence differ from human one??

Machine Intelligence does not imply thinking in a human-like way

Intelligence and computation

Computation (or computable by algorithm) is an <u>intuitive</u> concept – an explicit effective set of instructions to find the answers to any of a given class of problems in finite steps can be precisely defined by the computational models (computability) Turing machine, recursive functions, automata etc.

all these computational models are identical

i.e., the class of problems computable by the algorithm is identical to the class of problems solved by the computational models

Computation is typically carried out by an <u>electronic digital</u> computer, but might also be carried out by a person or by a mechanical device of some sort (machine)

- simulating intelligence by computation

It failed to precisely define intelligence as something like computation by some mathematical models

AI vs. brain

Big puzzle: brain \rightarrow mind (conscious, thinking, understanding) \rightarrow intelligence

The brain is an <u>existence</u> reference of intelligent machines to imitate

- E.g., birds were a reference for heavier-than-air flight
 - shouldn't just copy it, like a kite and earlier airplane
 - airplanes were inspired by birds
 - they use the same basic principles for flight aerodynamics and compressible fluid dynamics
 - but airplanes don't flap wings and have feathers

Al needs to understand the **principle** of intelligence

What is the equivalent of aerodynamics for understanding intelligence??

Cognition and recognition

Roughly, intelligence is regarded as two levels Recognition – a process of interpretation of perception and sensory information, e.g., hearing, vision, feeling

Cognition – a mental process of acquiring knowledge and understanding through thought, experience, sense perception etc.

– knowledge through thought: thinking even without experience
 or sense perceptions, e.g., concept formation

(cognition does not necessarily depend on sense perception; memory through sense perceptions can aid in cognition)

-- knowledge through experience: your own or someone else

 – knowledge through senses: perceptions can lead to thought processes and acquisition of knowledge

They are closely related in general

Weak AI: a special purpose computer system can solve a problem in some respect of human-level intelligence

- succeeded from the beginning of AI

Strong AI: a general-purpose computer system can solve a class of problems in almost all respects of human-level intelligence

- AGI (Artificial General Intelligence)
- not succeeded yet

Views of AI fall into four categories

Thinking humanly	Thinking rationally
Acting humanly	Acting rationally

Acting humanly: The Turing test

- <u>Can a machine think</u>??
- Operational test for intelligent behavior: Imitation Game



- Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes
- Anticipated all major arguments against AI in following decades
- Suggested major components of AI: knowledge, reasoning, language understanding, learning, etc.

The following interaction from Turing's paper

Q: Please write me a sonnet on the topic of the Forth Bridge.

A: Count me out on this one. I never could write poetry.

Q: Add 34957 to 70764.

A: (Pause about 30 seconds and then answer as) 105621.

Given the fact that you can **fool** some of the people all the time it is not clear how rigorous this particular standard is

Note: language plays a special role in human behavior, not seen in other animals

 much of how we deal with new situations involves using what we have read or been told earlier using language

Reading: Turing A, Computing machinery and intelligence, 1950

Some Turing test $programs^{\#}$

- ELIZA, MegaHAL, TIPS, A.L.I.C.E etc.
- Chatbots: MGONZ, NATACHATA, CyberLover etc. (chatbots.org)
- The Chatterbox challenge
- The Loebner Prize for Turing-test-like competition from 1991-2020, no winner

Related tests

• OpenAl ChatGPT – not yet

Play "Human or Not" yourself

https://www.humanornot.ai/

Challenge: The Turing test is not reproducible or amenable to mathematical analysis

#: requirement but may be self-taught due to limited time

Thinking humanly: Cognitive Science

1960s "cognitive revolution": information-processing psychology replaced prevailing orthodoxy of behaviorism

Scientific theories of internal activities of the brain

- What level of abstraction? "Knowledge" or "circuits"

- 1) Predicting and testing behavior of human subjects (top-down)
- 2) Direct identification from neurological data (bottom-up)

Both approaches (roughly, Cognitive Science and Cognitive Neuroscience) are now distinct from AI

Cognitive Science and AI share one principal direction

Brains

 10^{11} neurons of >20 types, 10^{14} synapses, 1ms–10ms cycle time Signals are noisy "spike trains" of electrical potential



Artificial neural networks

Artificial neural networks (ANN/NN): artificial neurons mimic the way biological brain with clusters of biological neurons connected by axons – an oversimplification of real neurons, but its purpose is to develop an understanding of what networks of simple units can do

The neural network's approach is called **connectionism** in Al

Resurgence under the name deep learning, distinct from the brains and cognitive science

Artificial brain projects#

Artificial Brain: direct human brain emulation using artificial neural networks on a high-performance computing engine

- IBM Blue Brain project (grant from Pentagon, 2008) Google etc.
- BRAIN Initiative (US, 2013)
 The Human Brain Project (Europ, Japan)
- China Brain Project (China, proposal from 2018)
- All failed

Challenge: Artificial neural networks and artificial brains are simpler to create general intelligent actions directly without the principle of intelligence

Thinking rationally: Logic

Aristotle: what are correct arguments/thought processes?

Originally, logic is study of thought, or intelligence but mathematical logic by symbolic method intended to study inferences in mathematics

Various forms of logic:

notation and rules of derivation for thoughts may or may not have proceeded to the idea of mechanization

The direct line through philosophy, mathematics and logic to Al so-called logicist in math

The logical approach is called **symbolism** in Al

Knowledge and common sense

Knowledge is the power of intelligence, with especially common sense – knowing, and solving problems by using knowledge

What is common sense??

How is having common sense any different from being well-trained on large amounts of data?

Common sense is not explained, but

rely on our routines of behavior that we have learned over time

act in situations that are sufficiently unlike the routines we have seen before

Common sense is critical to human-level intelligence and AI

Al would bring logic back to the original goal

Challenge: Not all intelligent behavior is mediated by mathematical logic

Rational behavior: doing the right thing

right thing: that is expected to maximize goal achievement, given the available information

A rational agent acts to achieve the best (expected) outcome

Viewpoints of rational agents something like engineering

(1) all the skills needed for the Turing test allow an agent to act rationally

(2) logical inference is one but not all of the possible mechanisms for achieving rationality

(3) human behavior is adapted for agent design

No matter symbolism vs. connectionism

Challenge: The rational agent doesn't necessarily involve thinking

Symbolism vs. connectionism

Symbolism & cognition

• E.g., logic can not deal with hearing

• Foundations of AI include problem-solving, knowledge, reasoning, planning, decision, machine learning (except for deep learning), natural language understanding, etc.

Connectionism & recognition

• Generative AI orGenAI (Adaptive AI/data-driven AI): connectionism toward recognition \Leftarrow main stream after 2000

• E.g., neural networks can not deal with a deduction (100% correct)

• Active in AI is deep learning and its applications such as computer vision, speech, natural language processing, etc.

Symbolism vs. connectionism[#]

Two different approaches to AI

- connectionism: current popular in AI, industry and society
- symbolism: breakthrough anytime

Challenging each other

• cycle between "spring" and "winter"

Keep constant temperature: good manner in the study of AI Neurosymbolic methods: integration of symbolism and connectionism

- All share one principal direction
- The available theories do not explain anything resembling human-level general intelligence

What are the principles of intelligence??

- What are the principles of human intelligence?
- What is machine intelligence?

In principle, you have to learn all AI

An interactive proof assistant for writing and checking mathematical proofs \leftarrow symbolism (logic)

- Users write math proofs using the formal language

- LEAN checks the proofs for correctness and consistency

- If the proof is valid, LEAN provides a formal verification of the theorem or construction

• Research: formalize and verify math theorems and constructions (formalizing math)

• Industry: formal verification of mathematical properties and computer software, etc.

• Education: as a tool for teaching formal reasoning, logic, and proof techniques

leanprover.github.io

Example: ChatGPT

A conversational assistant (model) for generating human-like text (video/audio) \leftarrow connectionism (deep learning)

- Users type a query or prompt into the chat interface
- ChatGPT will generate a response

- engaging in conversation (follow-up asking), utilizing the output, refining, and iterating, evaluating and applying

- Research: Natural language processing, AI for science
- Industry: E-commerce (customer support), content generation, language translation, healthcare, etc.

• Education: Students can use it for study support (including coursework), research assistance, and writing assistance to enhance their learning and productivity (revolution in education)

chat.openai.com

— You can find and use many similar models free of charge

Example: Doing math with LEAN & ChatGPT

• Leveraging ChatGPT for math inquiry

- Conceptual understanding: seeking explanations, examples, and insights into intricate math concepts and theories

- Problem-solving assistance: ChatGPT can provide step-by-step solutions, offer problem-solving strategies, and assist mathematicians in tackling challenging math problems

• Combining LEAN and ChatGPT

- Optimizing mathematical exploration: mathematicians can combine the formal reasoning capabilities of LEAN with the natural language interactions of ChatGPT to optimize their math exploration and research endeavors

- Holistic problem-solving: the integration of Lean and ChatGPT creates a holistic problem-solving environment, allowing mathematicians to engage in formal reasoning while receiving conversational support for their mathematical inquiries

AI as interdiscipline

logic, methods of reasoning	
mind as physical system	
foundations of learning, language, rationality	
formal representation and proof probability	
algorithms, computation, (un)decidability, (in)tractability	
adaptation, perception and motor control	
experimental techniques (psychophysics, etc.)	
knowledge representation	
grammar	
physical substrate for mental activity	
homeostatic systems, stability	
simple optimal agent designs	
decision and operations (e.g., information processing)	
AI is a discipline of computer science	

Brief history

- 1943 McCulloch & Pitts: Boolean circuit model of brain
- 1950 Turing's "Computing Machinery and Intelligence"
- 1952–69 Early AI (early enthusiasm, great expectations)
- 1950s Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
- 1956 Dartmouth meeting: "Artificial Intelligence" adopted (AI birth)
- 1965 Robinson's complete algorithm for logical reasoning (resolution)
- 1966–73 AI discovers computational complexity Neural network research almost disappears
- 1969–79 Early development of knowledge-based systems
- 1980– Al becomes an industry
- 1986-93 Expert systems industry busts: "Al Winter"
- 1986– Neural networks return to popularity (deep learning) ALife, GAs, soft computing
- 1987– Rapid increase in technical depth of mainstream AI: AI as a science

AI age

- 1995– Intelligent agents
- 2000– Semantic web and web services
 - 2001 Big data (very large data sets)
- 2007 Artificial General Intelligence (AGI)
- 2010– Smart earth and smart products, Internet of things AI embedded in the infrastructure of almost every industry (ambient intelligence, human-machine intelligence)
- 2012 deep learning
- 2015– AI age coming
- 2022 Generative AI (say ChatGPT)
- -Present +AI: Internet/internet of things+AI \rightarrow industry+AI AI+: AI for science (AI4S) \rightarrow AI for society

Al Index at aiindex.org (reports on the state of the art in Al)

Which of the following can be done at present?

• Play a decent game of ping-pong

- Play a decent game of ping-pong
- Drive safely along a curving mountain road

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket
- Win the national championship Chinese chess
- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket
- Win the national championship Chinese chess
- Discover and prove a new mathematical theorem

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket
- Win the national championship Chinese chess
- Discover and prove a new mathematical theorem
- Design and execute a research program in molecular biology

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket
- Win the national championship Chinese chess
- Discover and prove a new mathematical theorem
- Design and execute a research program in molecular biology
- Write an intentionally funny story

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket
- Win the national championship Chinese chess
- Discover and prove a new mathematical theorem
- Design and execute a research program in molecular biology
- Write an intentionally funny story
- Give competent legal advice in a specialized area of law

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket
- Win the national championship Chinese chess
- Discover and prove a new mathematical theorem
- Design and execute a research program in molecular biology
- Write an intentionally funny story
- Give competent legal advice in a specialized area of law
- Translate spoken English into spoken Chinese in real time

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
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- Discover and prove a new mathematical theorem
- Design and execute a research program in molecular biology
- Write an intentionally funny story
- Give competent legal advice in a specialized area of law
- Translate spoken English into spoken Chinese in real time
- Converse successfully with another person for an hour

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket
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- Converse successfully with another person for an hour
- Perform a complex surgical operation

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket
- Win the national championship Chinese chess
- Discover and prove a new mathematical theorem
- Design and execute a research program in molecular biology
- Write an intentionally funny story
- Give competent legal advice in a specialized area of law
- Translate spoken English into spoken Chinese in real time
- Converse successfully with another person for an hour
- Perform a complex surgical operation
- Walk with robot secretary in downtown

- Play a decent game of ping-pong
- Drive safely along a curving mountain road
- Drive safely along in downtown
- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at supermarket
- Win the national championship Chinese chess
- Discover and prove a new mathematical theorem
- Design and execute a research program in molecular biology
- Write an intentionally funny story
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- Translate spoken English into spoken Chinese in real time
- Converse successfully with another person for an hour
- Perform a complex surgical operation
- Walk with robot secretary in downtown

AI for science[#]

Generative AI has revolutionized the way scientists conduct research and make discoveries

• Mathematics: solving complex math problems, proving theorems, generating new conjectures, and replacing classical math methods Major achievement: The use of AI to solve mathematical problems that were previously unsolvable

• Physics: analyzing complex physical systems, optimizing experimental designs, and predicting the behavior of quantum systems

• Chemistry: predicting chemical reactions, designing new molecules, and optimizing drug discovery processes

 Biology: enabling the analysis of large genomic and proteomic datasets, say AlphaFold

 Earth sciences: analyzing satellite imagery, modeling climate change, and predicting natural disasters

• Astronomy, etc.

An agent is an entity that perceives and acts in an environment

Agents include

- animal agents
- human agents
- robotic agents (robots)
- software agents (softbots)
- – internet agents
- – crawler
- --- webbot
- – email agent
- -- search agent, etc.
- chatbots
- etc.

Single agent or usually multi-agents (so-called distributed AI)

Agents and environments



An agent is anything that can be viewed as <u>perceiving</u> its environment through <u>sensors</u> and <u>acting</u> upon that environment through <u>actuators</u>

Sensors and actuators[#]

A sensor measures some aspect of the environment in a form that can be used as input by an agent

- vision, hearing, touch

- active sensing: send out a signal (such as radar or ultrasound) and sense the reflection of this signal off of the environment \Rightarrow IoT (Internet of Things)

Perception provides agents with information about the world they inhabit by interpreting the response of sensors

Actuators

- hands, legs, vocal tract etc.
- robotaxi: those available to a human driver
- e.g., accelerator, steering, braking, and so on

Example: Vacuum-cleaner world

Example: Robot cleaner, say, iRobot Roombat



Percepts: location and contents, e.g., [A, Dirty]

Actions: Left, Right, Suck, NoOp

An agent is completely specified by the agent function: maps from percept histories to actions

$f: \mathcal{P}^* \to \mathcal{A}$

For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance

Find a way to implement the rational agent function concisely

Example: A vacuum-cleaner agent

Percept sequence	Action
[A, Clean]	Right
[A, Dirty]	Suck
[B, Clean]	Left
[B, Dirty]	Suck
[A, Clean], $[A, Clean]$	Right
[A, Clean], $[A, Dirty]$	Suck
:	:

What is the **right** function? Can it be implemented in a program?

The agent program runs on the physical architecture to produce the agent function

```
agent = architecture + program
program = algorithm + data
```

The agent program takes a single percept as input and keeps internal state

```
def Skeleton-Agent( percept)

persistent: memory, the agent's memory of the world

memory ← UPDATE-MEMORY(memory, percept)

action ← CHOOSE-BEST-ACTION(memory)

memory ← UPDATE-MEMORY(memory, action)

return action
```

The algorithm is described by the pseudocode

Other forms of algorithm

function SKELETON-AGENT(percept) returns action // output result inputs: percept, input from sensors // may be omitted persistent: memory, the agent's memory of the world memory ← UPDATE-MEMORY(memory, percept) action ← CHOOSE-BEST-ACTION(memory) memory ← UPDATE-MEMORY(memory, action) return action // output

The algorithm is described by the pseudocode

Other forms of algorithm

A procedure for the skeleton agent that takes a single percept as input, keeps internal state

```
Procedure of Skeleton-Agent
Input: percept
Output: action
memory the agent's memory of the world
1. memory ← UPDATE-MEMORY(memory, percept)
2. action ← CHOOSE-BEST-ACTION(memory)
3. memory ← UPDATE-MEMORY(memory, action)
```

The algorithm is described by the pseudocode

Other forms of algorithm

Popular forms of pseudocode are written by Lagorithmic packages (e.g., algorithm2e)

1: **procedure** Skeleton-Agent(*percept*)

- 2: *memory*: the agent's memory of the world
- 3: $memory \leftarrow UPDATE-MEMORY(memory, percept)$
- 4: $action \leftarrow CHOOSE-BEST-ACTION(memory)$
- 5: $memory \leftarrow UPDATE-MEMORY(memory, action)$
- 6: return action

An algorithm is an explicit effective set of instructions for a computing procedure

- may be used to find the answers to any of a given class of questions

- can be precisely defined by computational models, e.g., Turing machine, etc.

Analysis of algorithms, independently of the particular implementation and input

- time complexity: speed in seconds
- e.g., the worst $T_{worst}(n)$ or the average $T_{avg}(n)$
- space complexity: memory consumption in bytes

Complexity analyzes problems rather than algorithms

O-notation: asymptotic analysis

 $T(n) \text{ is } O(f(n)) \text{ if } T(n) \leq k f(n) \text{ for some } k \text{, for all } n > 0$

 $O(n^k)$ for some k: <u>polynomial</u> time/space, called P or "easiness" Otherwise, exponential time/space, e.g., $O(2^n)$, called NP, hardness

- a class of nondeterministic (Turing machine) polynomial problems

guess a solution and then verify whether the guess is correct in polynomial time

- NP-complete problems (the hardest subclass of NP) - - co-NP (-complete) is the complement of NP (-complete) "yes" and "no" answers reversed

Theorem: either all the NP-complete problems are in P or none of them is

Algorithm#

$\underline{NP = P??}$

if you could try all the guesses at once, or you were very lucky and always guess right the first time

#P: counting problems corresponding to decision problems in NP decision problems have a yes-or-no answer, counting problems

have an integer answer: how many solutions

at least as hard as any NP problems

PSPACE: require a polynomial amount of space, even on a non-deterministic machine

it is believed that PSPACE-hard problems are worse than NPcomplete problems although it could turn out that NP = PSPACE, just as P = NP The pseudocode is a simple language to describe algorithms

- similar to programming languages like C, Java, Lisp or Python

- informal use of mathematical formulas or ordinary English to describe parts

- Persistent variables (global and local variables): a variable is given an initial value the first time a function is called and retains that value on all subsequent calls to the function. The agent programs use persistent variables for memory. Variables have lowercase italic names.
- Function as values: The value of a variable is allowed to be a function. Functions and procedures have capitalized names
- Default values for parameters: "function F(x, y = 0) return a number" means that is an optional argument with default value 0, i.e., the calls F(3, 0) and F(3) are equivalent

- Indentation is significant: the scope of a loop, conditional or statement block
- Assignment: " $x \leftarrow value$ " means that the right-hand side evaluates to the left-hand side variable
 - **Destructuring assignment**: " $x, y \leftarrow pair$ " means that the right-hand side evaluates to a two-element tuple, and the first element is assigned to x and the second to y. Or "for each x, y in *pair* do"
- **Conditional** if c then ... (else) ...: if the condition c is hold then doing something; otherwise doing something else

The pseudocode

• Loops

- for x in c do: the loop is executed with the variable x bound to successive elements of the collection c
 - or for each x in c do
- for i = 1 to n do: the loop is executed with bound to successive integers from 1 to n inclusive
- while c (condition) do": means the condition is evaluated before each iteration of the loop, and the loop exits if the condition is false

or loop $c \cdots$

- repeat ··· until c: the loop is executed unconditionally the first time, then the condition is evaluated, and the loop exits if the condition is true; otherwise the loop keeps executing (and testing at the end)

The pseudocode

- Generator: a function that contains yield is a generators that generates a sequence of values, one each time the yield expression is encountered. After yielding, the function continues execution with the next statement, say, "generator G(x) yields number" defines G as a generator function
- Data types: data structure
 - Lists: [x, y, z], [first|rest]
 - **Sets**: $\{x, y, z\}$
 - Arrays start at 1: as in usual mathematical notation, not 0 as in Python
- \bullet // the explanations can be given as remark

Note: Try to write the algorithm in natural language, then use Al assistants (say ChatGPT/DeepSeek) to translate to the pseudocode for practice

The algorithms in the pseudocode can be implemented in Python, Java, C/C++, Lisp and Prolog etc.

The code for each topic is divided into four directories:

- agents: code defining agent types and programs

- algorithms: code for the methods used by the agent programs
- environments: code defining environment types, simulations

 domains: problem types and instances for input to algorithms (Often run algorithms on domains rather than agents in environments)

*: no requirement for the exam and learned as extended knowledge

```
import environment as en
import domain as do
import action as ac
def skeleton_agent(percept):
    m = []
    m = do.push(percept)
    a = ac.choose()
    #chosen from action class
    m = ac.update()
    return a
```

Note: encourage to code by Python, but programming language and programming methodology are prerequisites which are out of the basic requirement of this course

Example: A vacuum-cleaner agent

def TABLE-DRIVEN-AGENT(*percept*)

Python: A vacuum-cleaner agent*

```
def Table_Driven_Vacuum_Agent(table):
    """
    A table is provided as a dictionary of all
    {percept_sequence:action} pairs.
    """
    percepts = []
    def agent(percept):
        percepts.append(percept)
        action = table.get(tuple(percepts))
        return agent
```

Hint: It can be executable Python code

Python: One more*

```
def Table_Driven_Vacuum_Agent():
    """Tabular approach towards vacuum world
    >>> agent = Table_Driven_Vacuum_Agent()
    >>> environment = VacuumEnvironment()
    >>> environment.add_thing(agent)
    >>> environment.run()
    >>> environment.status == {(1,0):'Clean', (0,0) : 'Clean'}
    True
    .....
   table = {((loc_A, 'Clean'),): 'Right',
             ((loc_A, 'Dirty'),): 'Suck',
             ((loc_B, 'Clean'),): 'Left',
             ((loc_B, 'Dirty'),): 'Suck',
             ((loc_A, 'Dirty'), (loc_A, 'Clean')): 'Right',
             ((loc_A, 'Clean'), (loc_B, 'Dirty')): 'Suck',
             ((loc_B, 'Clean'), (loc_A, 'Dirty')): 'Suck',
             ((loc_B, 'Dirty'), (loc_B, 'Clean')): 'Left',
             ((loc_A, 'Dirty'), (loc_A, 'Clean'), (loc_B, 'Dirty')): 'Suck',
             ((loc_B, 'Dirty'), (loc_B, 'Clean'), (loc_A, 'Dirty')): 'Suck'}
   return Agent(Table_Driven_Vacuum_Agent(table))
```

Hint: It can be executable Python code

Python: Translating pseudocode to code*

Note: Using ChatGPT/DeepSeek or Code Assistants (say Github Capilot/AlphaCode) to translate the pseudocodes to almost executive codes in popular programming languages

Agents interact with environments through sensors and actuators



Four basic types in order of increasing generality:

- simple reflex agents
- model-based reflex agents
- goal-based agents
- utility-based agents

All these can be turned into

- learning agents

Simple reflex agents


Example: A vacuum-cleaner agent

def REFLEX-VACUUM-AGENT([*location*,*status*])

if status = Dirty then return Suck
else if location = A then return Right
else if location = B then return Left

Simple reflex agents

def SIMPLE-REFLEX-AGENT(percept) persistent: rules, a set of condition-action rules $state \leftarrow INTERPRET-INPUT(percept)$ $rule \leftarrow RULE-MATCH(state, rules)$ $action \leftarrow rule.ACTION$ return action

Model-based reflex agents



Reflex agents with (internal) state transition model - how the world works

Goal-based agents



Utility-based agents





MAS (multi-agent systems): an agent interacts with neighboring agents

a complex task is divided into multiple smaller tasks, each of which is assigned to a distinct agent

Applications

- modeling complex systems
- smart grids
- computer networks
 - cloud computing, social networking, security, routing
- etc.

+: optional for undergraduate but requirement for graduate students

Coordination: managing agents to collaboratively reach their goals

- . consensus achieving a global agreement
- . controllability using certain regulations to transmit a state
- . synchronization aligning each agent in time with other agents
- . connection connecting to each other
- . formation organizing in a structure

Communication: communicating among agents

Fault detection and isolation (FDI): a faulty agent may infect other agents that it collaborates with

Task allocation: allocation of tasks to agents considering the associated cost and time

Localization: each agent has a limited view (only its neighbors)

The way agents communicate and connect

- Flat all agents are regarded as equals
- Hierarchy agents have tree-like relations

• Holon - agents are organized in multiple groups which are known as holons based on particular features (e.g., heterogeneity), holons are then multiplied layered

• Coalition - agents are temporarily grouped based on their goal

• Team - agents create a team and define a team goal that differs from their goal

• Matrix - each agent is managed by at least two head agents

• Congregation - agents in a location form a congregation to achieve their requirements that they cannot achieve alone

AI News

- You can find AI almost everywhere in media in everyday life
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